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Techniques for Accurately Determining a Current Location of a Device

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Abstract:

This publication describes techniques for accurately determining a current location of a computing device over time while reducing power consumption. The computing device may include a Pretrim Manager configured to direct a processor of the device to perform a sequence of techniques to update the current location of the device over time using a combination of techniques, each technique varying in accuracy and power consumption. For example, the combination of techniques may include a true-range multilateration, a dead reckoning, an atmospheric-pressure adjustment, and a true-range inertial multilateration. Each technique is repeated at a unique frequency to minimize power consumed by the device while accurately determining the current location of the device to enhance a user experience.

Keywords:

Locating, altitude, movement, inertia, pressure-aided true-range inertial multilateration, pretrim algorithm, location determination, position determination, true-range multilateration, atmospheric pressure, barometric pressure, dead reckoning, inertial navigation

Background:

Users may desire to know a location of a computing device (e.g., a mobile phone) with spatial and temporal accuracy to support operations and/or applications of the device. For example, a user may need to know their location while hiking in a wilderness to better determine their location relative to a trail map. Without spatial and temporal accuracy of their location, the user may become lost or confronted with danger.

Some computing devices utilize a multilateration technique to accurately determine the location of the device using, for example, a global navigation satellite system (GNSS) receiver, an Angle of Arrival (AoA) of wireless signals, a Time-of-Flight (ToF) distance measurement, and so forth. However, the multilateration technique may require significant power consumption by the device. To reduce power consumption, some devices (e.g., robotics, drone implementations) may use a dead-reckoning technique based on an inertia of the device. However, the dead-reckoning technique may increase a spatial uncertainty associated with the location of the device. As a result, there are barriers preventing the user from determining the location of their computing device with spatial and temporal accuracy while reducing power consumption of the device.

Description:

This publication describes techniques for accurately determining a current location of a computing device over time while reducing power consumption. While the example computing device described in this publication is a mobile phone, other types of computing devices may also support the techniques described in this publication.

A computing device may include one or more processors, transceivers for transmitting data to and receiving data from a base station (e.g., wireless access point, another computing device), sensors (e.g., a location sensor, a GNSS receiver, a global positioning satellite (GPS) receiver, an inertial sensor, an atmospheric-pressure sensor, an accelerometer, a gyroscope), a computer-readable medium (CRM), and/or an input/output device (e.g., a display, a speaker, a microphone). The CRM may include any suitable memory or storage device, such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or flash memory. The CRM includes device data (e.g., user data, multimedia data, applications, and/or an operating system of the device), which are executable by the processor(s) to enable the techniques described herein.

The device data may include a Pretrim Manager. The processor(s) of the computing device perform operations under a direction of the Pretrim Manager to determine a current location of the computing device using a combination of techniques including a true-range multilateration, a dead reckoning, an atmospheric-pressure adjustment, and a true-range inertial multilateration. By utilizing a combination of techniques, the Pretrim Manager may reduce the power consumption of the device and increase the speed of updates associated with the current location of the device to enable spatial and temporal accuracy.

The Pretrim Manager may direct the processor(s) to perform a sequence of techniques to update the current location over time of the device, as illustrated in an example sequence of Figure 1. The current location may include X-, Y-, and Z-coordinates corresponding to axes of a three-dimensional space that are orthogonal with respect to each other. First, the processor(s) may determine an initial position of the device by executing an initialization using a true-range multilateration technique and an absolute pressure measurement.

The absolute pressure measurement may be performed to determine a Z-coordinate associated with the initial position at an initial time. The absolute pressure measurement may refer to a measurement using an absolute scale (e.g., starting at a minimum point or zero value). Therefore, pressure measurements taken after the initialization may include relative-pressure measurements (e.g., atmospheric-pressure adjustments) that are measured relative to a previous pressure measurement to detect a change in altitude (e.g., Z-coordinate) associated with the current location of the device. Pressure measurements may be performed on the device using a sensor (e.g., a Micro-Electro-Mechanical Systems (MEMS) nano pressure sensor) with an altitude accuracy of approximately one meter.

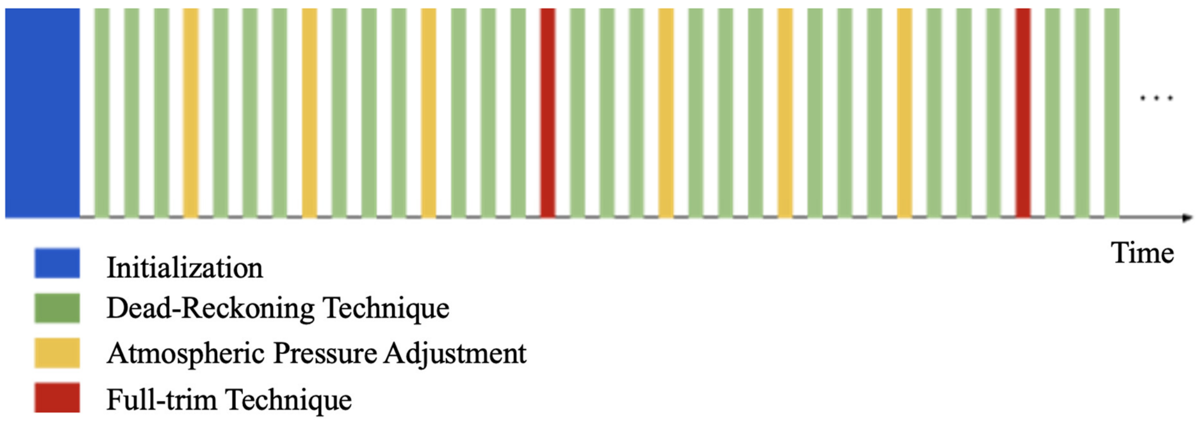

Figure 1

To determine an X-coordinate, a Y-coordinate, and a Z-coordinate of the initial position of the device, a true-range multilateration technique may be utilized to determine a distance from the device to multiple stations of known locations. These stations may include, for example, antennas, clocks, or high-power transmitters that may enable the techniques described herein. To increase the accuracy of this true-range multilateration technique, a least-squares solver may be used by the technique to best fit a set of data points provided by the multiple stations.

After the initial position of the device has been determined, the Pretrim Manager may direct the processor(s) to apply a Gauss-Newton algorithm to best fit the set of data points using a non-linear least-squares solver, weighted towards the altitude. A result of this algorithm may include an absolute position of the device at the initial time. During the initialization, an orientation of the device may be determined by gathering data from an inertial measurement unit (IMU) for a configured duration of time to later enable the dead-reckoning technique. The IMU may measure a force, an angular rate, or the orientation of the device using, for example, accelerometers or gyroscopes. The configured duration of time may include a duration from the initial time to a later time. The position of the device is determined at this later time using both the true-range multilateration technique weighted towards the altitude and the data from the IMU. A calculation is then performed to determine the orientation of the device at the initial time by incorporating information obtained by the accelerometer and the gyroscope.

A final step of the initialization may include determining the orientation of the device at the later time using the dead-reckoning technique. The dead-reckoning technique may determine the current location of the device by starting with the initial position and adding subsequent velocity vectors repeatedly over time. For example, the Pretrim Manager may direct the processor(s) to use a 6-axis IMU (e.g., containing three axes of rotation and three axes of linear motion) that sums an angular acceleration over time to approximate an angular velocity for each axis. These angular velocities are summed to approximate the orientation of the device. Relative-cartesian accelerations may be rotated into a consistent absolute-coordinate space, and accelerations may be summed to approximate a velocity at each point in time. The velocities may be summed to produce the current location of the device. However, the dead-reckoning technique may produce errors over time due to drift.

After the initialization has been completed, the dead-reckoning technique is repeated periodically to provide rapid updates on the current location of the device using the IMU. Additionally, the processor(s) may perform periodic relative-pressure measurements at a frequency that may differ from a frequency of updates obtained using the dead-reckoning technique. In the example sequence of Figure 1, the dead-reckoning technique is performed three times more often than the relative-pressure measurement. The frequency of updates using each technique after initialization may vary, and the sequence of Figure 1 is shown only for example.

The relative-pressure measurement may be measured to determine a change in the Z-coordinate of the current location and compensate for any drift associated with the dead-reckoning technique.

A full-true-range inertial multilateration (full-trim) technique is also performed periodically after the initialization and at a frequency that may differ from both the frequency of updates obtained using the dead-reckoning technique and the relative-pressure measurements. The full-trim technique is similar to the initialization, except that the initial position may already be known, and the full-trim technique may be weighted with results from the dead-reckoning technique. The full-trim technique may select a most-recent location of the device and apply an iterative Gauss-Newton (e.g., non-linear) algorithm to increase the accuracy of that current location. The true-range multilateration technique may be performed with an additional station point added at the most-recent location to weight a measurement of the current location of the device based on previous results using the dead-reckoning technique. This weight may be adjusted to improve performance. Additionally, the orientation of the device at the current location may be determined using the full-trim technique. The full-trim technique may require more power consumption than the dead-reckoning technique or relative-pressure measurements and therefore may be used less often to preserve power of the device to enhance a user experience.

The computing device may repeat the dead-reckoning technique, the relative-pressure measurements, and the full-trim technique for a duration of time required by the user, as illustrated in the example sequence of Figure 1, to accurately determine the current location of the device over time while reducing power consumption.

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